A Multi-sensor, Low Volume, Automated Culture System for Space Biology Experiments

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Optical density (absorbance) is commonly used in microbiology to measure cell concentration and other colorimetric indicators. It is the main type of bioscience data returned from the BioSentinel small spacecraft mission, which was recently launched as a secondary payload on Artemis I. The flight unit takes absorbance measurements of yeast cultures at 570 nm, 630 nm, and 850 nm to track cell concentration and oxidation-reduction (redox) state of the metabolic indicator dye alamarBlue over time [1].

Because the data returned from a small spacecraft mission is necessarily limited, BioSentinel uses a specialized ground-based experiment apparatus to map the absorbance data onto several other parameters. This culture apparatus is composed of a polycarbonate base and lid which contain ports for several commercial sensors, including a standard 12 mm dissolved oxygen probe, gaseous CO_2, fluid pressure, and two micro-probes for measuring pH and redox potential. It also contains a pressure relief valve, a rubber membrane for culture interaction, and a 12mm port for the custom optical probe designed to match in-flight measurements. Modules in two corners expand the culture volume into narrow columns, enabling solid-state optical density measurement and dielectric spectroscopy. The apparatus can be fit to a plate for magnetic stirring.

The apparatus's optical probe allows mapping between the flight unit's optical data and the additional parameters measured by the ground-based experiments. Within the probe, a linear actuator pulls a plunger, drawing culture volume into the optical path. The actuator then pushes out the plunger and culture volume, cleaning any stray yeast from the inside surface of the probe. The probe chassis is 3D-printed from biocompatible resin with the optoelectronics cured inside an optically clear conformal coat which functions as a lens.

To optimize the probe's dimensions, including optical path, a test harness was developed to manipulate and measure distance while the LED light sources and photodiode detector are in operation. The test harness was composed of two 3/64" thick polycarbonate plates mounted to a set of calipers. The LEDs and photodiode were mounted on the outside of each plate. A cuvette of sample fluid was then clamped between the plates in line between the LEDs and photodiode.

The test harness generated a 78% signal change between water and a dye standard for the green (570 nm) LED, a 90% signal change for the red (630 nm) LED, and a 25% signal change between water and overgrown yeast for the infrared (850 nm) LED.

The improvements to the ground experiment apparatus (culture volume reduction, inclusion of an optical probe to measure flight-like optical data, and magnetic stirring for culture homogeneity) allow for more flight-like measurements to be taken and more accurate mapping of these additional parameters to the optical data returned from the flight unit. This enhancement to mission science return will give insight into how deep space radiation may affect human biology for future long-term space exploration.

References:

[1] Santa Maria, S. R. *et al.* (2020). BioSentinel: Long-term *saccharomyces cerevisiae* preservation for a deep space biosensor mission. *Astrobiology*. https://doi.org/10.1089/ast.2019.2073